University College London

TODAY
SMART CITIES
LECTURES

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TOMORROW

URBAN MODELS

LECTURES

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The Smart Cities Lectures

1: Introduction to the Course

Michael Batty

http://www.spatialcomplexity.info/

6 July 2018

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The lectures are divided into four sessions with two parts to each lecture session, each lasting about 70 minutes.

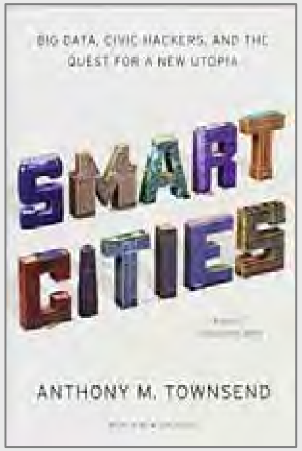
We have a break of 5-10 minutes in the middle of each session. In this first presentation, we will briefly sketch the topics and launch into a history of computing and smart cities

Let me begin by saying this is not a technical course, it is an impressionistic set of lectures that introduces you to ideas about Smart Cities.

Smart Cities have many definitions. The one we will use is based on exploring the way information, specifically digital information is changing the physical as well as socio-economic structure of our cities. Computers and digital communications are being continuously embedded into the fabric of the city. The information they relay is changing the way we behave.

Background Reading

The web site http://www.spatialcomplexity.info/ is where the lectures will be placed. I have adopted Anthony Townsend's book *Smart Cities* as good background. You can read a review here: http://www.spatialcomplexity.info/archives/2419
Something to read today, download the following paper
http://link.springer.com/content/pdf/10.1140%2Fepjst%2Fe2012-01703-3




Eur. Phys. J. Special Topics 214, 481–518 (2012)

DOI: 10.1140/epjst/e2012-01703-3

THE EUROPEAN PHYSICAL JOURNAL SPECIAL TOPICS

Regular Article

Smart cities of the future

M. Batty[1,a], K.W. Axhausen[2], F. Giannotti[3], A. Pozdnoukhov[4], A. Bazzani[5], M. Wachowicz[6], G. Ouzounis[7], and Y. Portugali[8]

Let me point you to some more reading: there is a special issue of **Built Environment** from last year and I will put my two papers up on my blog – you will be able to find these at www.spatialcomplexity.info

I can't put all the issues up on the blog because they are not open access – only my own – and I don't know if the University here gets **Built Environment** but I am sure you can retrieve these from various web sites; and here is the list of papers. In fact if these have not been circulated then I can circulate them

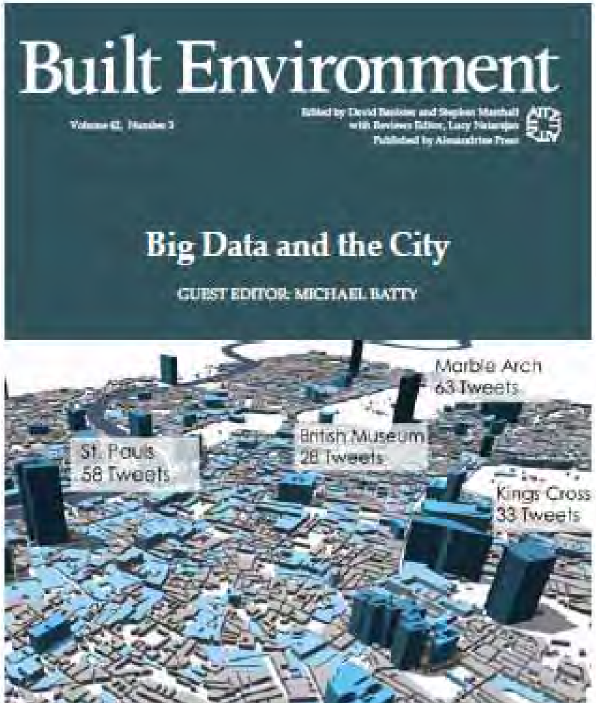
Big Data and the City

Editor: Michael Batty
Centre for Advanced Spatial Analysis, University College London

Built Environment

Volume 42, number 3, September 2016

Big data is everywhere, largely generated by automated systems operating in real time that potentially tell us how cities are performing and changing. A product of the smart city, it is providing us with novel data sets that suggest ways in which we might plan better,anddesignmore sustainable environments. The articles in this issue tell us how scientists and planners are using big data to better understand everything from new forms of mobility in transport systems to new uses of social media. Together, they reveal how visualization is fast becoming an integral part of developing a thorough understanding of our cities.



http://www.spatialcomplexity.info/archives/3026

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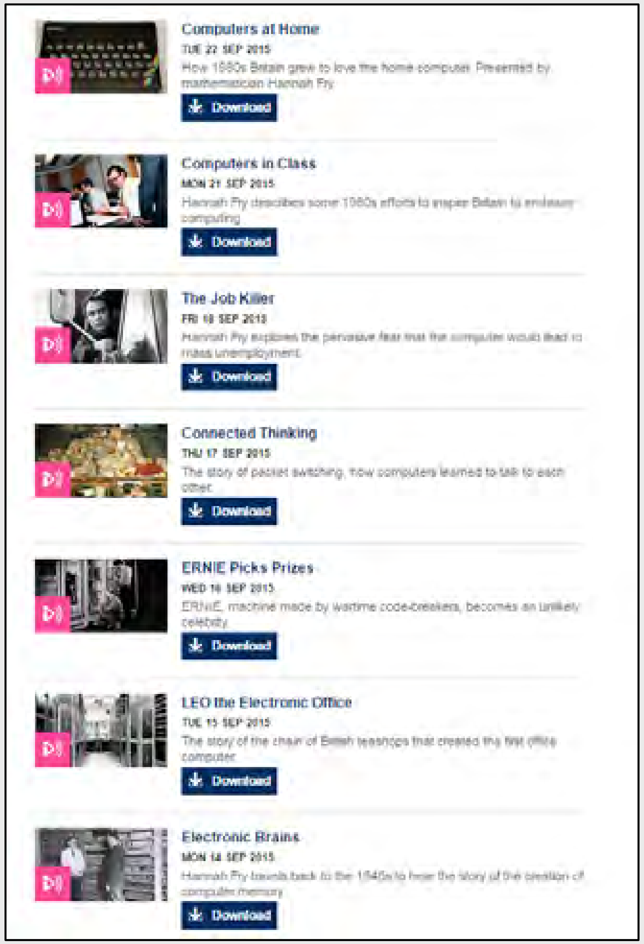
Background Listening and Watching

My colleague Dr, Hannah Fray has released 10 radio programmes on BBC Radio 4 which you can download as podcasts from the BBC i-Player site or from the links below. These programmes will tell you a vast amount about the history

Please look at these BBC Podcasts



To STREAM http://www.bbc.co.uk/programmes/b06bq6j1
To PODCAST http://www.bbc.co.uk/programmes/b06bq6j1/episodes/downloads

An Outline of the Course

Session 1: Introduction to Smart Cities

1: The Smart City as Information Technology: A History: A Walk Through the Smart City

2: Turing's Legacy & The Laws of Computing

Session 2: Smart Cities Are About Information, Hardware And Software: Data And Technology

1. The Wired City: Computable City: Information Infrastructure
2. Data and Technology: Big Data, Open Data, Data Infrastructures

Session 3: Big Data, Network Data, Measuring Disruption in the 24 Hour City

Session 4: New Media and the Smart City:
Networks Again, Virtual Cities, & Crowdsourcing

I cannot tell you the history of all this from the year dot to modern times but I develop some themes about computing and smart cities

And I want to point you to my blog where you can get the complete series of lectures which I have given at ASU and Tel-Aviv. These are at

http://www.spatialcomplexity.info/tau-lecture1

http://www.spatialcomplexity.info/outline-of-the-lecture-course

Some references you can download

http://www.spatialcomplexity.info/technicity

University College London

Session 1: Introduction to Smart Cities

1: The Smart City as Information Technology: A History: A Walk Through the Smart City

Michael Batty

30th June 2017

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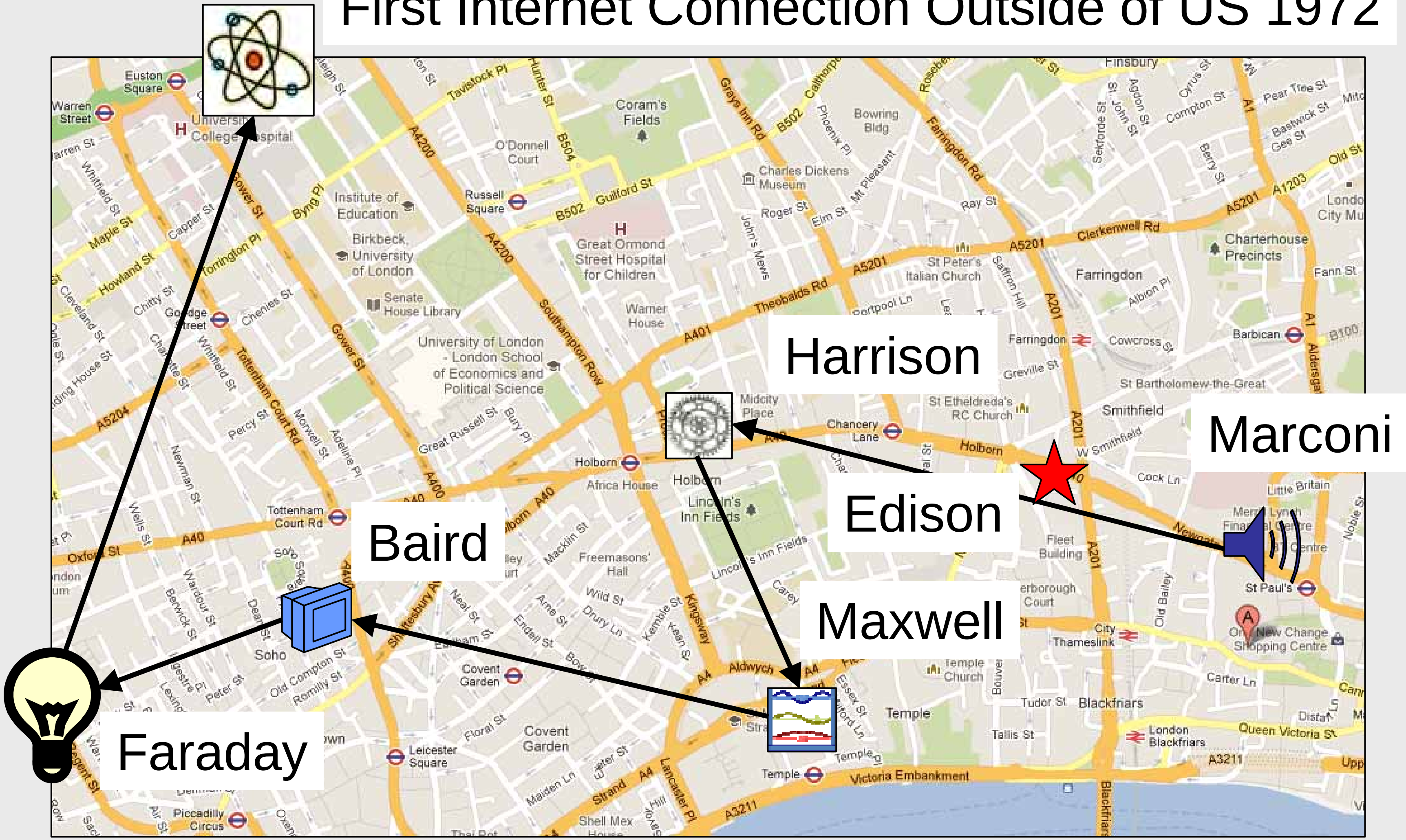
First Internet Connection Outside of US 1972



Worth noting that after I had presented this talk, I found out that the Edison Electric Company installed the world's first (little) power station at Holborn to light nearby buildings such the central criminal court and the GPO

Marconi, 1890s

Marconi made the first public wireless transmission from the General PO Office to PO Office South in 1896

John Harrison, Clockmaker to the Board of Longitude, 1750s

John Harrison invented mechanical clocks that worked at sea so position could be determined accurately

Maxwell, Physicist, 1860s

$$dU = TdS - PdV \implies \left(\frac{\partial T}{\partial V}\right)_S = -\left(\frac{\partial P}{\partial S}\right)_V$$

$$dA = -SdT - PdV \implies \left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$$

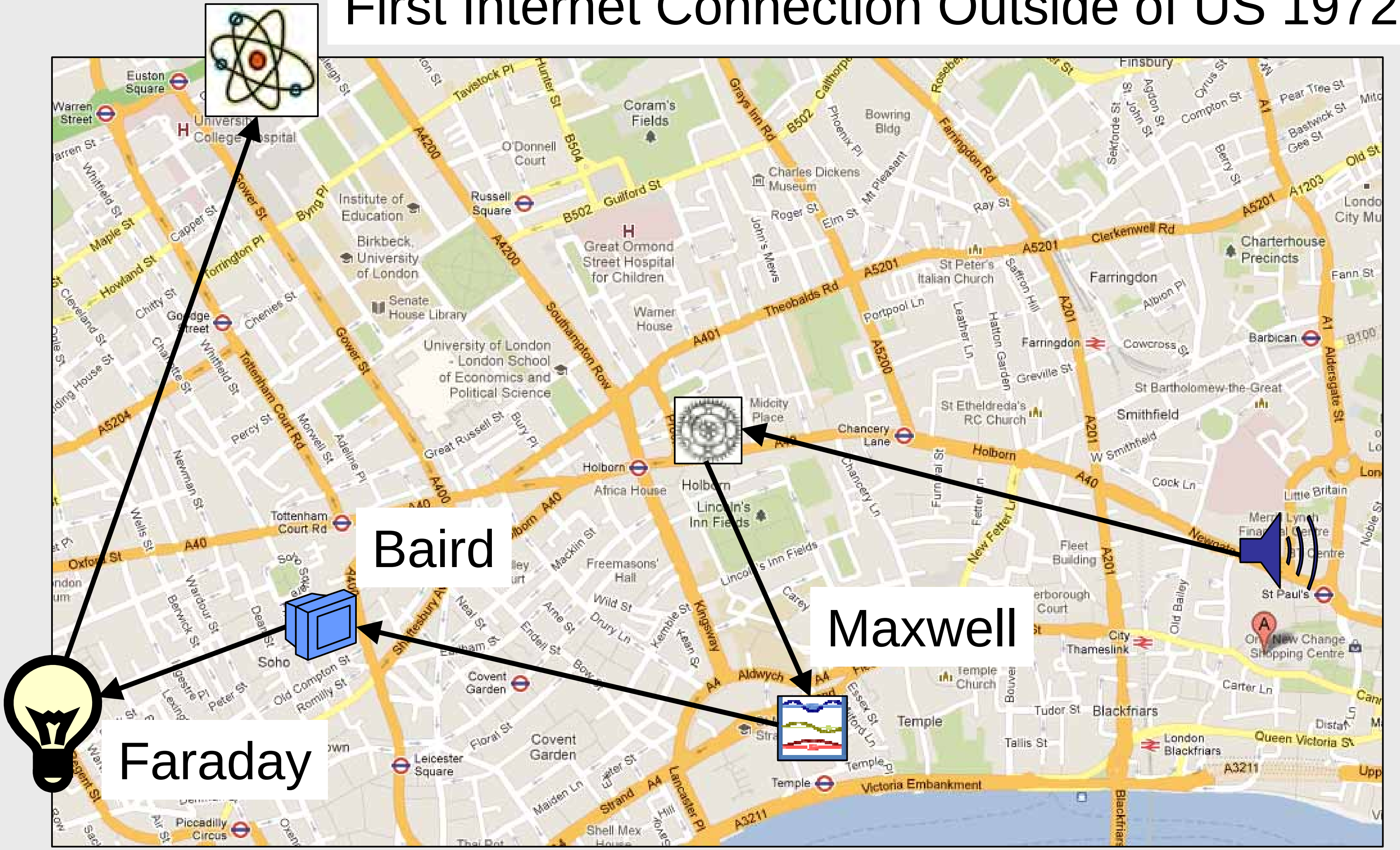
$$dH = TdS + VdP \implies \left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$$

$$dG = -SdT + VdP \implies -\left(\frac{\partial S}{\partial P}\right)_T = \left(\frac{\partial V}{\partial T}\right)_P$$

Maxwell pulled it all together at Kings in 1860

Note Bush House, the original home of the BBC is nearby

First Internet Connection Outside of US 1972



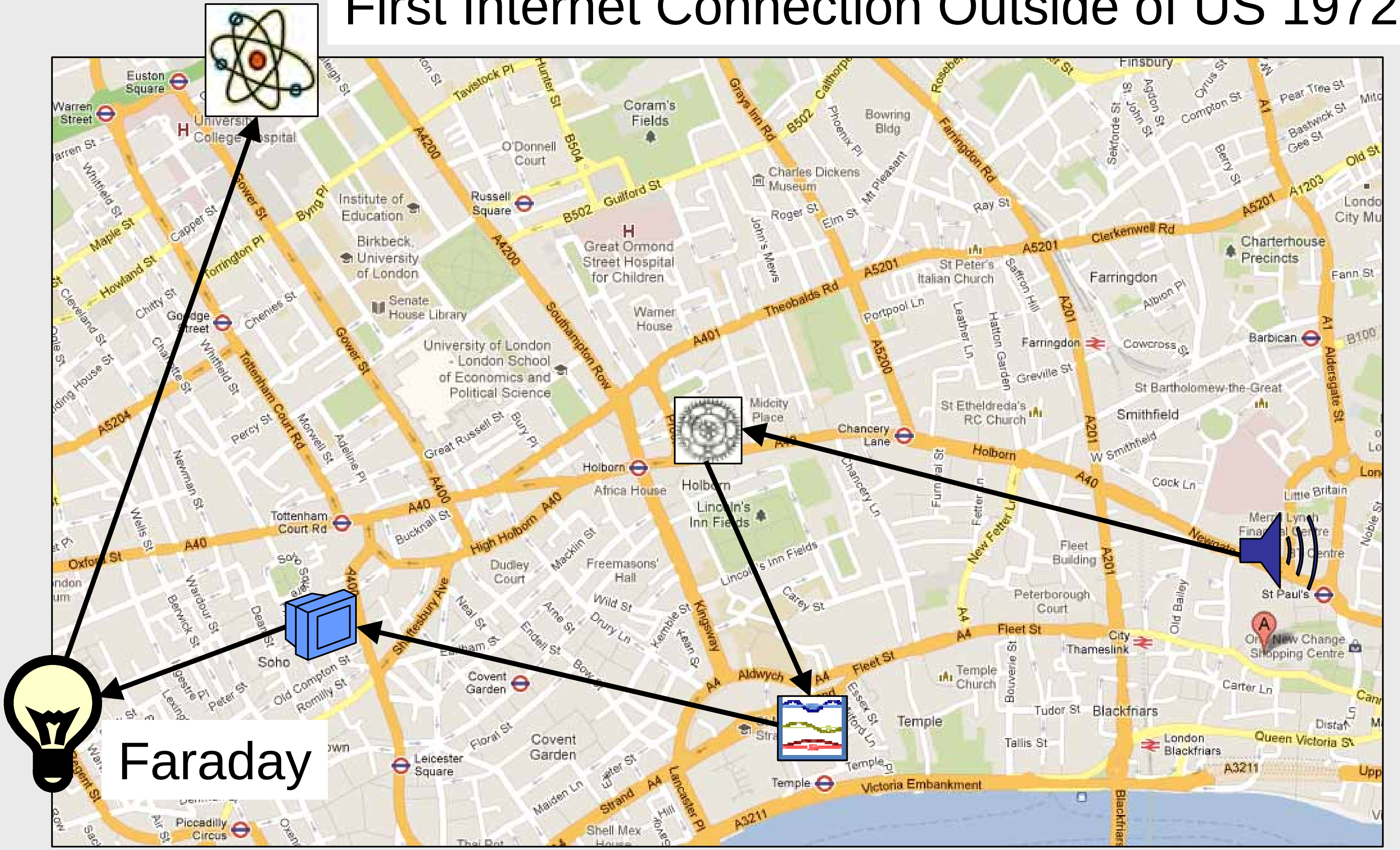
Baird, Inventor of TV, 1926

John Logie Baird demonstrated TV for the first time in 1925-1927 in London's Soho

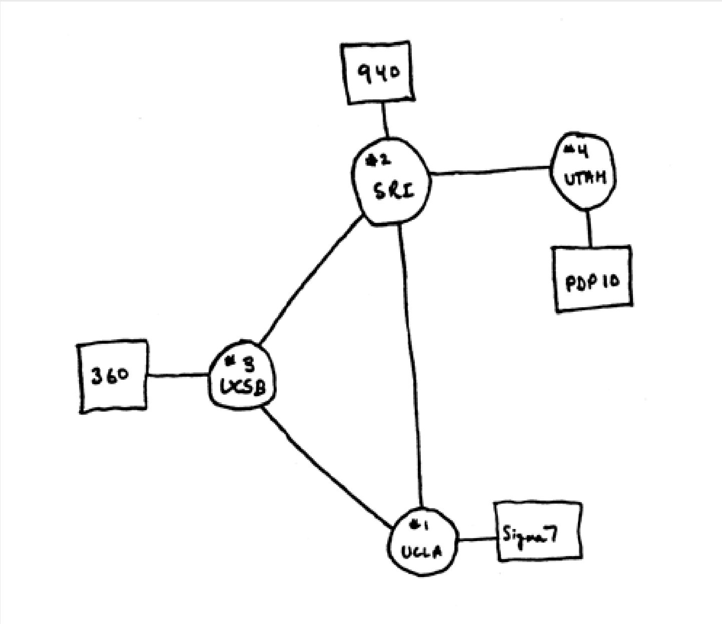
Faraday, Electromagnetism, 1820s

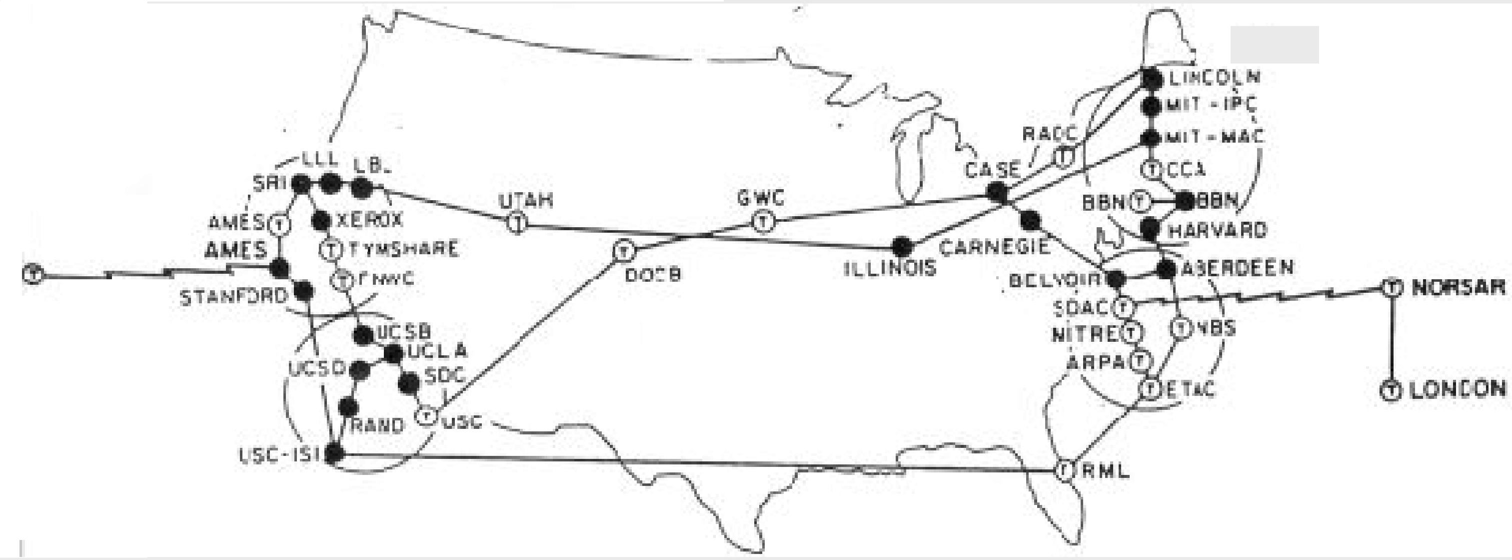
Michael Faraday explores electromagnetism in the 1820-30's at the Royal Institution

First Internet Connection Outside of US 1972

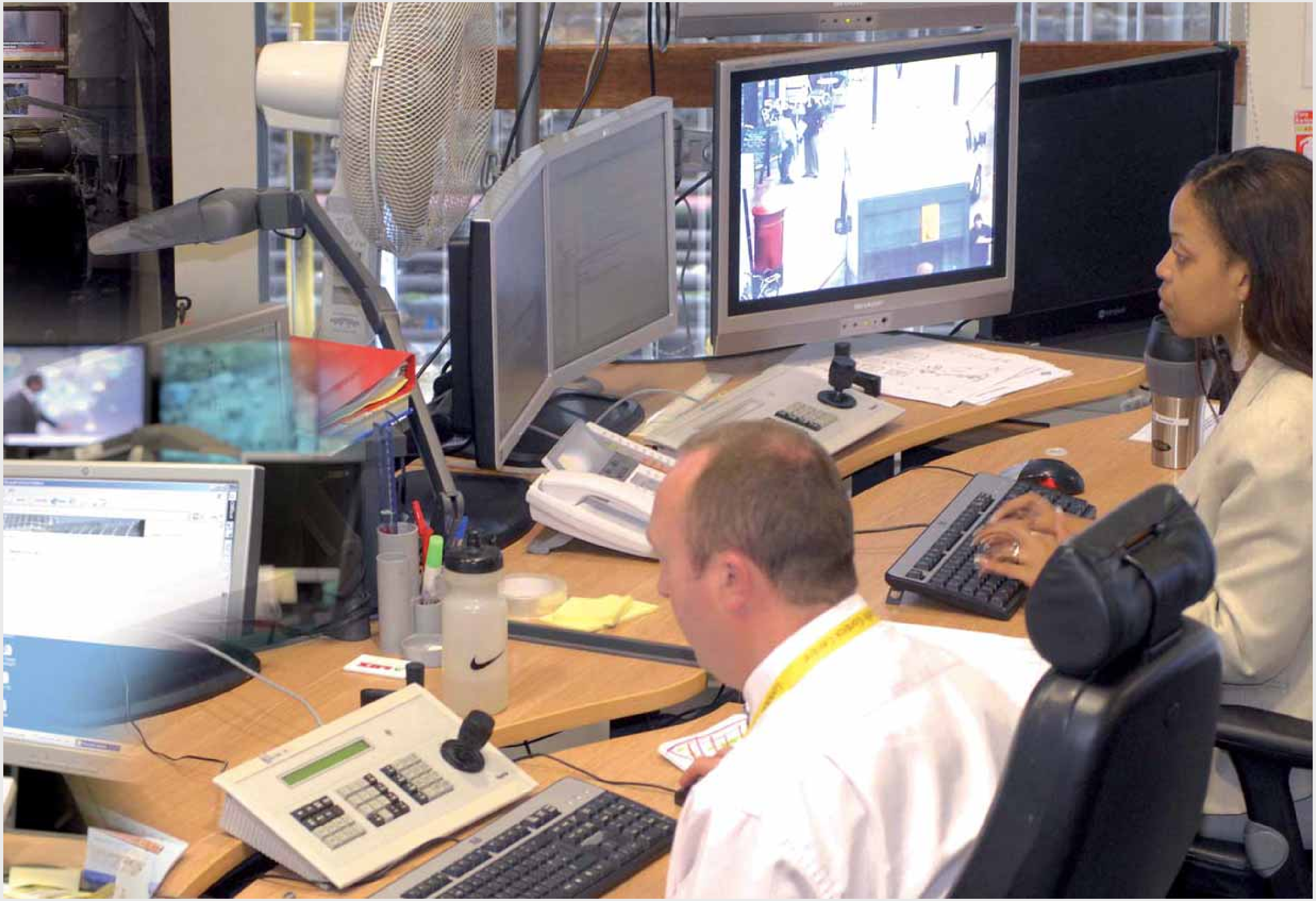


The first internet connection outside the US at UCL in 1972

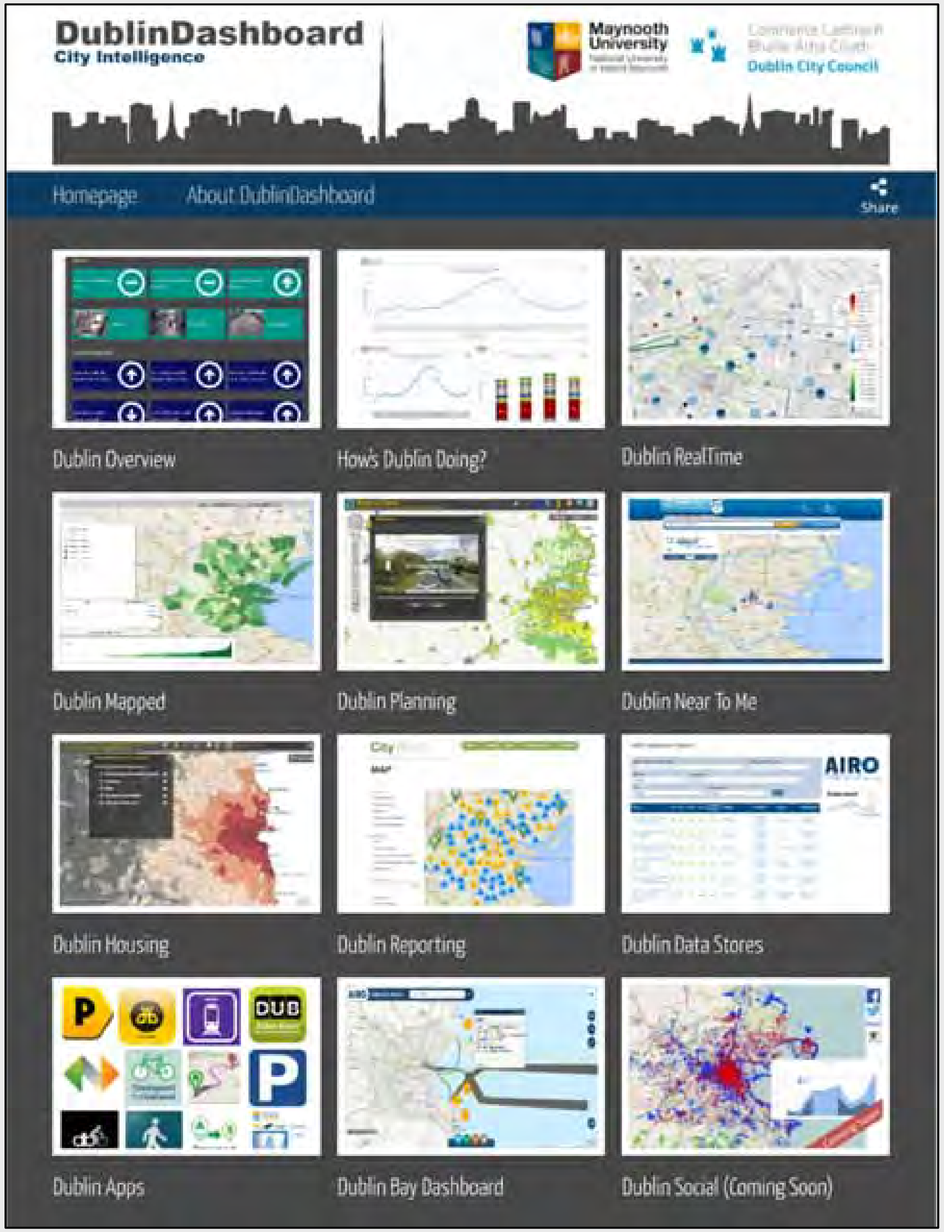




The modern day – traffic control systems in London




CENTRO DE OPERAÇÕES
PREFEITURA DO RIO



DublinDashboard
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Maynooth University
Dublin City Council
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About DublinDashboard
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Dublin Overview
How's Dublin Doing?
Dublin RealTime
Dublin Mapped
Dublin Planning
Dublin Near To Me
Dublin Housing
Dublin Reporting
Dublin Data Stores
Dublin Apps
Dublin Bay Dashboard
Dublin Social (Coming Soon)


CITY of BOSTON
Employee Demographics
Last Updated: May 4, 2016
Gender
Overall
Male 46.3%
Female 53.7%
Annual Rate
Tenure - Years
By Annual Rate
By Ethnic Group
Ethnicity

http://vis.oobrien.com/panopticon/

The key messages can be easily seen from our walk through the city and we will list ***five essential themes*** that recur again and again.

1. Cities are about information and ***smart cities in this context are about digital information, not about hardware per se*** – how cities are shaped is about how we use information.
2. Information is comparatively invisible compared to past technologies and our second theme is that ***smart cities tend to be invisible*** – ICT is invisible –wires in the road and wires in the sky are not so easy to figure out in terms of what is being transmitted but of even greater invisibility are wireless communications, particularly social communications. Thus the study of smart cities is not like watching traffic on subway or the road system. We need instruments to sense it.

3. Cities grow from the bottom up by and large. There are millions of decisions that lead to cities, and ICT is being introduced from the bottom up – cities grow from the bottom up – ***<u>cities and their ICT evolve and grow organically from the bottom up</u>*** – there are lots of examples like new towns which are model smart cities like Masdar in UAE, these are the exception. Smart cities tend to be the bigger cities where ICT is being introduced slowly insidiously and quietly

4. Smart cities are not really just about computers in the built environment, not just about what have been called Wired Cities in the past. They are more about how we, not the city, use information, and how cities becoming smart which means us becoming smarter. So a fourth message is that ***<u>smart cities are about how information services are best delivered</u>*** and how citizens use those services.

5. Information is essentially costless – or the cost of transmission is very small compared to physical movements and transactions. Thus cities and citizens can acquire information from anywhere – that makes it global – ICT is intrinsically about the global city and ***<u>the smart city is thus a global city</u>***.

To figure out how all this works need to know something about how ICT is physically configured in cities but this is only a bit of smart cities. ICT makes cities more efficient, we think, but it is unclear if it makes them more equitable – it might. Clearly all sorts of past technologies have increased productivity in cities but this is the third industrial revolution that deals with ICT is tending to generate lower productivity gains that the previous two revolutions. At this point we pause and then come back for our second theme which about the origins of digital information.

Session 1: Introduction to Smart Cities

2: Turing's Legacy & The Laws of Computing

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30 June 2017

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SHUFE

2017 中国城市与区域实验室（CCRL）年会

How did it all begin – we will discuss the background to the development of the digital computer and then move to talk about how computing has developed in the last 70-80 years. But first we will say something about the motive force for computation and it technology and this involves us saying something about electricity, then logic. This lecture which is our second we will organize in the following topics.

- The Motive Force of Computation: Electricity
- The Representation of Numbers: The Binary System
- The Idea of an Algorithm: Turing
- Miniaturisation of Electric Circuits: Moore's Law
- Communications and Computation: Metcalfe's Law
- Hardware to Software to Dataware to Orgware, and then to to the modern day

The Motive Force of Computation: Electricity

Electricity – basic feature of all material. It is so widely part of nature that we simply take it for granted without knowing much about. It has a long history: the Greeks knew about it – electric fish – sparks – material has a charge – and when you bring materials into contact interesting things happen ….. when charges are in contact

Basic ideas of electricity began to be explored in early 1800s – We have seen the work of Michael Faraday at the Royal Institution but there were many developments in the 19th century – electricity came to be regarded as a force – a very powerful force, much more powerful than gravity and in some senses, electricity is the force that powers the modern world.

Force and waves – James Clerk Maxwell tied it all together mathematically– in fact we noted the place where Maxwell did some of his work at Kings College London in the 1860s. I think he also did quite a bit of it in Scotland and he was a little later than Michael Faraday. He went on to found the Cavendish Lab in Cambridge after his spell at Kings

But we must say that two others things were developed during the 19th century – first the telegraph by many people but particularly Morse of Morse code fame– a kind of early binary transmission system, and then the telephone. But both these were, like most of the internet based on wires not wireless – there is a very nice book by Tom Standage called **The Victorian Internet** worth reading about telegraph

So electric circuitry produced the power to drive this type of communication. It is basic.

The Representation of Numbers: The Binary System

Ok the basic nuts and bolts for moving information were established by the early 20th century – but what was to be moved – can we move anything – how do we convert data into a form that could be universal.

Here the binary number systems comes in – basically from classical times people had speculated that we could reduce numbers to simple pulses. In fact Francis Bacon in the 16th century laid out a kind of binary and implied that all numbers could be so transformed into 'yes' and 'no', 'on' and 'off' – but it was not until the 1930s that the binary number system was formalised and linked to electric circuits. This drew on George Boole's algebra which he developed in the mid-19th century.

Essentially if you can reduce all numbers to 0 and 1 and combinations therein and thereof, you can use switching to transmit them. The basic logic of this transmission was first demonstrated by Claude Shannon at MIT in his Masters thesis in 1937 and became the basis for numerical computation during the war years when the first large scale electronic – digital computers were built.

Before then in the 19th century, the first analog computers were built where switching was done mechanically as in Charles Babbage’s difference engine and many similar workable systems were developed at places like MIT in the 1930s and 1940s. The German code breaking machine Enigma was also based on such analog devices in the UK and our next computer pioneer Alan Turing was associated with this – there are movies about this if you are interested ….

I can’t give you a course in binary here but the essence of the idea is interesting and here is a table of our the first 10 decimal numbers are converted.

http://en.wikipedia.org/wiki/Binary_number

0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10 – (A)	1010

You can find out all about this on Wikipedia – how to use arithmetic on them. Essentially if you can reduce all numbers to 0 and 1 and combinations therein and thereof, you can use switching to transmit them.

The Idea of an Algorithm: Turing

The next step in the evolution of ICT which proceeded in parallel to developments in electricity/communications and number representation was even more profound.

This is the idea of the universal machine – using binary type system but more in terms of the development of a procedure for computation. Alan Turing showed in 1936 I think how an abstract machine – a Turing machine – could be built that could compute forever. Thereby he showed that computation was universal using these ideas in that it could in principle compute the computations necessary for a digital computer – i.e. itself. This idea of an algorithm is hard to define really, so I am going to quote from the Wiki entry ….

“He proved that some such machine would be capable of performing any conceivable mathematical computation if it were representable as an algorithm.

He went on to prove that there was no solution to (David Hilbert’s) *Entscheidungsproblem* by first showing that the halting problem for Turing machines is undecidable: in general, it is not possible to decide algorithmically whether a given Turing machine will ever halt.

Although Turing's proof was published shortly after Alonzo Church's equivalent proof using his lambda calculus, Turing had been unaware of Church's work.[25] Turing's approach is considerably more accessible and intuitive than Church's. It was also novel in its notion of a 'Universal Machine' (now known as a Universal Turing machine), with the idea that such a machine could perform the tasks of any other machine, or in other words, is provably capable of computing anything that is computable. Von Neumann acknowledged that the central concept of the modern computer was due to this paper.[26] Turing machines are to this day a central object of study in theory of computation.”

Turing died in early life in tragic circumstances in Manchester where he was then deputy director of the computer lab in 1954 ….

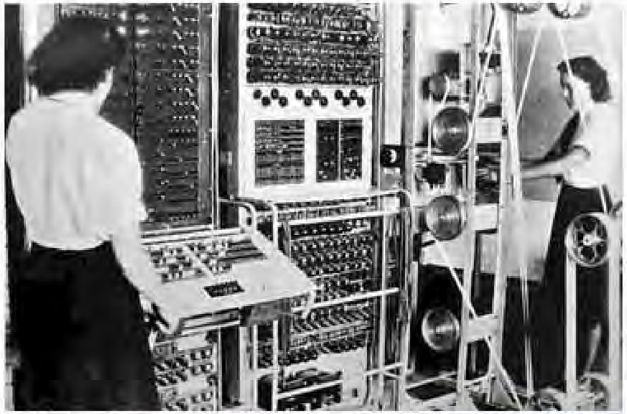
Here too could feature on our Walk Through the Smart City because he was born not so far away to the north and east of central London

Interesting to note in passing that both Turing and Shannon are known generally not for their major work – in fact Turing more for Enigma and Shannon more for information theory.

There are lots of online sources where you can explore the history of computing and code and networks such as the BBC web site

2001 Movie

Colossus computer



A Colossus Mark 2 computer being operated by Dorothy Du Boisson (left) and Elsie Booker. The slanted control panel on the left was used to set the "pin" (or "cam") patterns of the Lorenz. The "bedstead" paper tape transport is on the right.

Developer	Tommy Flowers assisted by Sidney Broadhurst, William Chandler and for the Mark 2 machines, Allen Coombs
Manufacturer	Post Office Research Station
Type	Special-purpose electronic digital programmable computer
Generation	First-generation computer
Release date	Mk 1: December 1943; Mk 2: 1 June 1944
Discontinued	8 June 1945
Units shipped	11
Media	Electric typewriter output Programmed, using switches and plug panels
CPU	Custom circuits using valves and Thyratrons. A total of 1600 in Mk 1 and 2400 in Mk 2. Also relays and stepping switches

Miniaturisation of Electric Circuits: Moore's Law

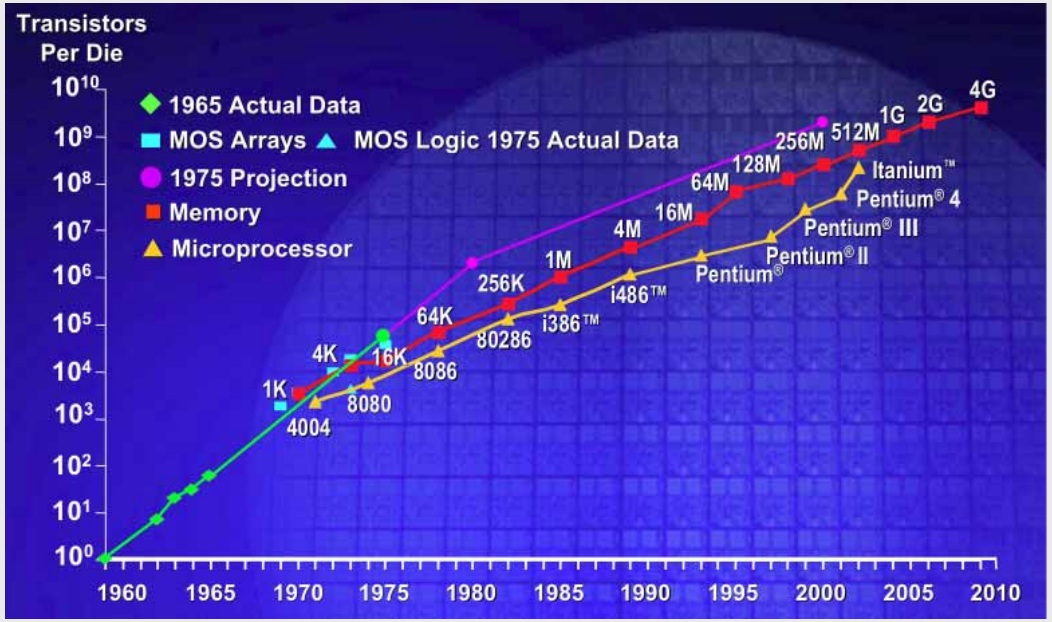
The fourth element in all this which is arguably the most important in that it made computation all pervasive was the invention of circuitry that relied on new materials – silicon

At Bells Labs in 1947, the transistor was invented by William Shockley, John Bardeen and Walter Brattain. This sets us on the road to miniaturisation. It was more about materials than numbers, about silicon as it happens

And this led to the story of Silicon Valley. Shockley went back home to the Valley, founded his own company that led to Fairchild Semiconductor that led to Intel – the rest is history as they say

In 1959, the integrated circuit was developed and then in 1971, the breakthrough – the microprocessor – all the circuitry needed for a computer on a single chip.

Gordon Moore one of the founders of Intel coined his famous law that ***the amount of circuitry/memory on the same sized chip was doubling every 18 months*** and has been ever since.



Communications and Computation: Metcalfe's Law

At the same time, there were rapid developments in networking and in the material of networking. In parallel to miniaturisation, fibre optics was invented.

Computers had begun to be networked from the very beginning but there ARPANET was founded to linked main frames across distance in 1969 and in the 1970s at Xerox Parc local area networking was invented in terms of the Ethernet.

There is much to say about all this but here it is worth noting that as computers get connected together, then they share resources and these increases as the rate of the number of connections of the network. This led to Metcalfe's Law – the ***value of a telecommunications network is proportional to the square of the number of connected users of the system (n^2).***

There is also Gilder’s Law and Sarnoff’s Law and so on. Let me state quickly five of these laws but there are more that relate to miniaturisation, memory, cost, value and so on of ICT.

Moore's Law: formulated by Gordon Moore of Intel in the early 70's - the processing power of a microchip doubles every 18 months; corollary, computers become faster and the price of a given level of computing power halves every 18 months.

Gilder's Law: proposed by George Gilder, prolific author and prophet of the new technology age in 1988 - the total bandwidth of communication systems triples every twelve months. New developments seem to confirm that bandwidth availability will continue to expand at a rate that supports Gilder's Law.

Metcalfe's Law: attributed to Robert Metcalfe, originator of Ethernet and founder of 3COM in the 1970s: the value of a network is proportional to the square of the number of nodes;

Sarnoff’s Law: states that the value of a broadcast network is directly proportional to the number of viewers, and believe it or not

Zuckerberg’s Law: the information that people share doubles each year

Hardware to Software to Dataware to Orgware to ….

Ok there are many many things we can say about modern computation and to finish this history so far, let me give you a rapid run down of how computing has changed through this process of miniaturisation and networking and

The 1950s and 1960s: ***The mainframe era*** – essentially users delivered by hand their programs to some central large computer which were operated behind closed doors. Programming and operation were completely separate. There was not such thing as software; the term is very hard to source – thinking versus machine operation has something to do with it but it gradually emerged I think in the 1970s and came in with a vengeance once the PC took off.

The 1970s: ***<u>The minicomputer era</u>*** – essentially users has their own small mainframes which were often networked with teletypes or even visual display units in star like fashion around the machine. There was some sense too that users needed to know more about the operating system than before as they had more control.

The 1980s: ***<u>The PC revolution</u>***: with the invention of the microprocessor, small computers became the norm but the end of this decade and the laptop or portable PC came onto the scene. Networks of machines appeared and by the 1990s one was connecting PCs to networks to act as go betweens between data and users and big computation on i and mainframes

The 1990s: ***<u>extensive networking</u>***, continued miniaturisation, the web and the emergence of hand held computers

The 2000s: ***hand held devices – phones, tablets and related devices*** – software and data on such devices and also continual computation

The 2010s+: ***Apps, many different devices***: some specialisation is beginning with respect to computers for different roles

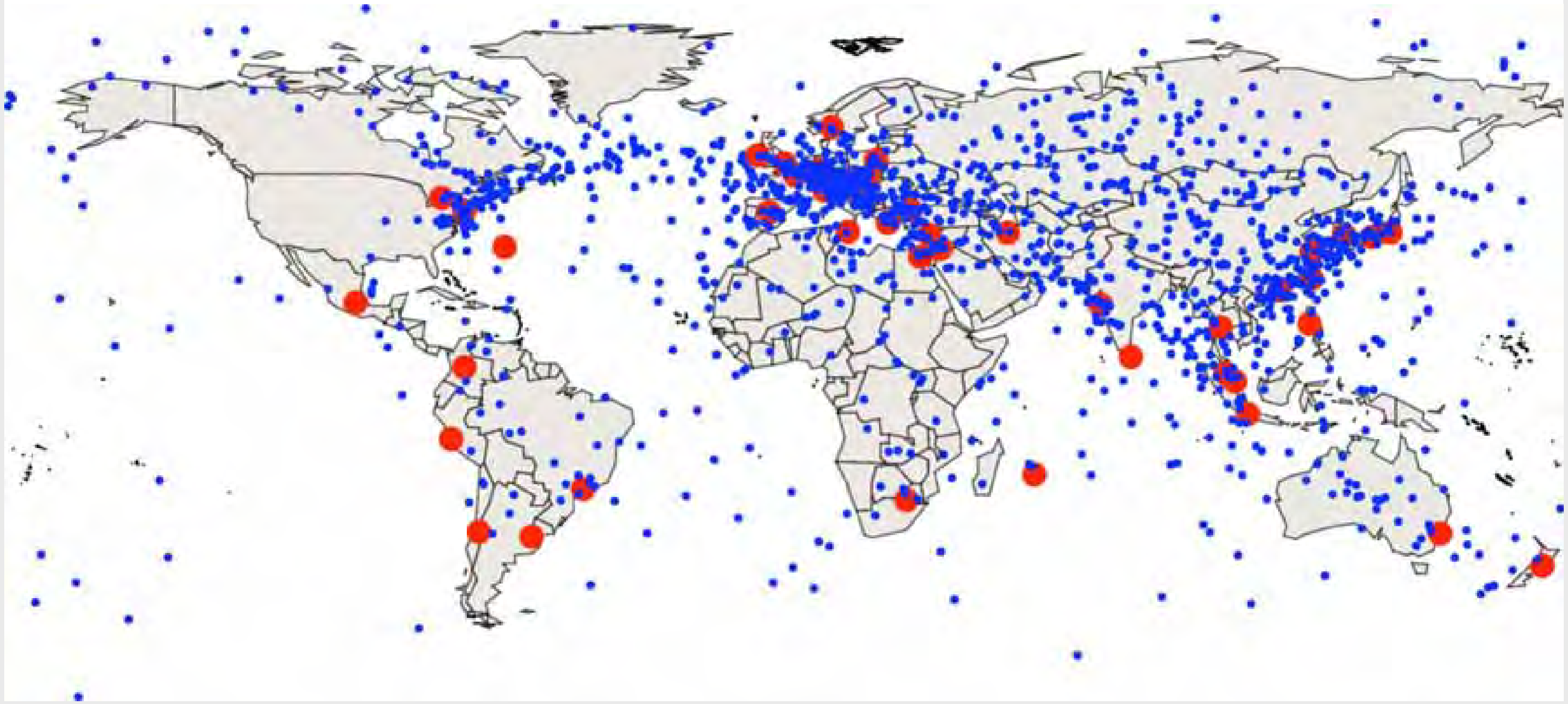
At the same time as computers have become smaller and faster and bigger in terms of memory, special purpose machines continue to be devised – supercomputers, parallel computation on arrays of devices, grid computing

The client-server architecture is now writ large. But in this value chain the value of hardware has fallen – this is Moore's Law in action. What has happened is that the value of Software has risen but it now appears that software is becoming so general that it is different combinations of software that are being devised. Hard to know if software is as important as it was.

Now if we look at other elements of computing, data and organisation, which we might refer to as dataware and orgware, then these are becoming more important in the value chain – how much more so is tricky to figure but organisation is absolutely key to good operation and integrated data too is key – orgware and dataware may well be the keys to the smart city, rather than hardware and software

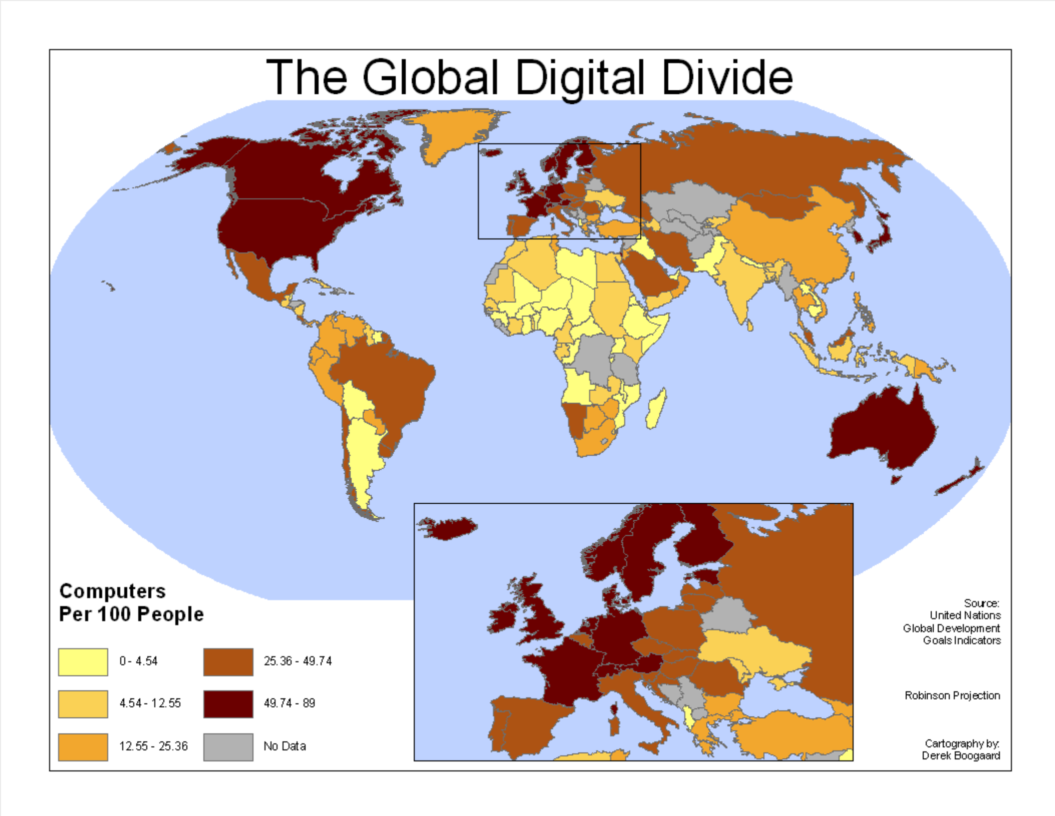
One last issue before we more to the next session is that graphics and interaction are all important too – and that right from the beginning, there was graphics of a kind. But not until the PC was graphics utilised in terms of the interface and only when memory was sufficient – Xerox Parc, then Apple led the way but so did the workstation companies – individual minicomputers. Graphics is key as we will see.

Financial Concentrations : High Frequency Trading



The Information Divide

I need to flag the fact that all these things are part of the smart city and the fact that smart cities are global in this sense. In some respects we should have maps of the use not the actual ownership and this is a key point. We will not say any more other than flag the divide as a recurring issue



The Impact of Technology on Distance and Time: Another Key to the Wired World and the Smart City

Ok – a long talk – but let me focus on my last theme because as geographic scientists and urban researcher we are clearly interested in space.

Clearly each wave of technology through the industrial revolutions has meant change in the way we interact – in particular the distances over which we can interact and also the speed of that interaction

First came the internal combustion engine and steam and this led to railways and then to automobile – so average distance that some one could travel increased dramatically from say 5 or 6 miles to 10s of miles, and the time taken decreased

Then came electricity and the telegraph and the phone with very long distances being possible in terms of communication, not physical travel so this was an information medium

The computer and ICT has accelerated all this and in fact it has led to almost continual communication

Air travel has led to global movement but in general we are still restricted by how long it takes to drive – however there are strange and insidious things going on with travel. It is hardly the death of distance but there are strange transformation going on with respect to locational decision-making and it is this that we need to get a handle in in terms of the smart city.

Productivity gains have slowed in fact due to the fact that most of what is now happening is improvement not massive disruptive change – we will continue to speculate here….

There are many references but look at

http://www.spatialcomplexity.info/technicity and read, peruse

Andrew Blum (2012) **Tubes: A Journey to the Center of the Internet**, Ecco, New York.

George Dyson (2012) **Turing's Cathedral: The Origins of the Digital Universe**, Vintage, New York.

Dava Sobel (1997) **Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time**, Walker and Company, reprint, New York

Tom Standage (2007) **The Victorian Internet: The Remarkable Story of the Telegraph and the Nineteenth Century's On-line Pioneers**, Walker and Company, reprint, New York.


Michael Batty
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